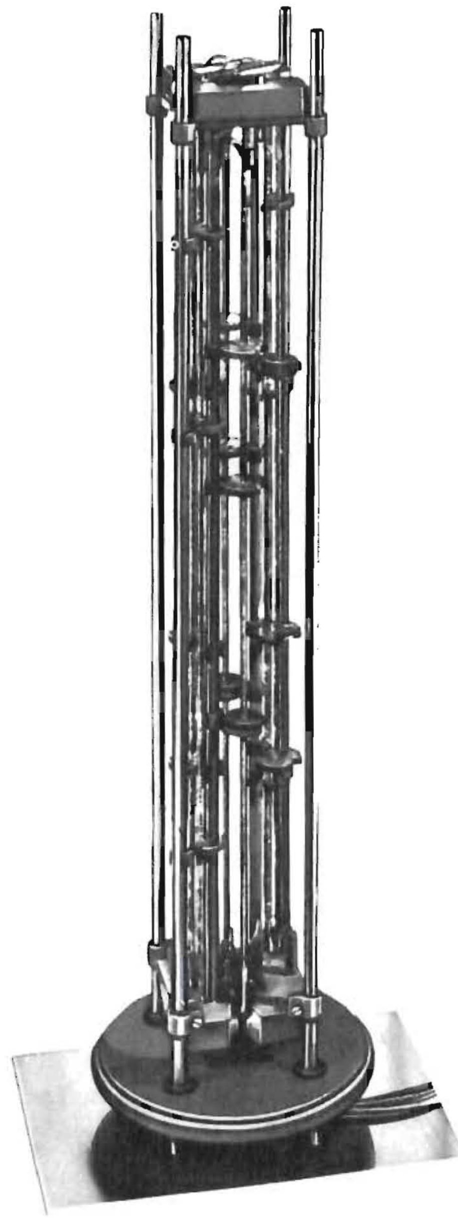


AKG BX 20E REVERBERATION UNIT

AKG REVERBERATION UNIT BX 20E

Modern recording techniques have made the use of artificial reverberation indispensable in studio operations. With few exceptions most musical recordings have reverberation added; even those done on location in halls with excellent acoustic characteristics, often use additional reverberation to enhance individual groups of instruments or the performance as a whole. There are currently two methods of producing high-quality reverberation:

1. the echo room
2. the reverberatory plate

While producing the highest sound quality, the echo chamber is expensive and cumbersome. To obtain a range of decay times, several rooms have to be constructed and the re-recording process is susceptible to vibration and noise.

The reverberatory plate provides a simpler means of producing artificial reverberation albeit with slightly lower sound quality. Decay time at higher frequencies is considerably longer than with natural reverberation, but this characteristic is often deliberately used in recording. The major disadvantage of the plate is its large size and weight and resultant immovability. This has proved a great handicap in outdoor recording or with a mobile van, as the sound engineer has to cope with a great variety of acoustically different recording problems. The customary practice of running special cables to the plate located in the studio is very expensive and often impossible because of distance and location. Hence AKG developed a new reverberation unit that is portable yet meets all the quality requirements for use in the studio.

A portable reverberation unit may be developed on the basis of the following techniques:

a) production of artificial reverberation by means of tape recorders

b) production of artificial reverberation by means of a mechanical plate that is much smaller than the one in use at present

c) production of artificial reverberation using electronic storage technique

d) production of artificial reverberation by means of a torsion transmission line (TTL)

After critical consideration of all these techniques, AKG has decided that TTL offers the best means for the realization of a portable reverberation unit, as space requirements are small and construction is relatively economical. However, some prejudices in connection with this method must be overcome as so far reverberation produced by various types of coil springs has not met studio quality requirements.

When judging the quality of reverberation the listener, in the final analysis, always uses the natural room as a standard. From the viewpoint of communication theory a natural room exhibits a highly complex transmission pattern with the following essential characteristics which must be met by any artificial reverberation device irrespective of the means used:

1) high density of resonance frequencies

2) high pulse density to duplicate the many sound paths

3) high degree of statistical diffusion in the frequency and time ranges - i.e. no regularity must exist in the two ranges concerned

4) reverberation must start 20 to 50 milliseconds after the original sound

5) frequency response that falls slightly at the high and low frequency extremes

6) a decay time frequency response that has a slight rise at low frequencies, while at high frequencies a slight fall is desirable

7) practical applications require variability of decay time

We can use the technique of TTL to meet these criteria in the following way: The high density of resonance frequency requires very long coil spring elements. According to experience, their length should correspond to a delay time of 300 milliseconds from beginning to end. Provided that the signal is fed into one end and picked up at the other end of the spring, this length yields a density of resonance frequency of 0.6 based upon the formula.

$$\eta = \frac{1}{\Delta F} \qquad \text{where } \Delta F = \frac{1}{2T}$$

ΔF = distance of two adjacent poles in the frequency spectrum

η = density of resonance frequency

T = delay time

This possible density of natural resonances is the starting point for all further development. The excellent reverberation quality is brought about by certain changes in density and distribution of these natural resonances by means which are described later.

In order to obtain the high pulse density as well as the statistical diffusion in the time and frequency range, it is necessary to vary the transmission properties of the spring statistically by changing the mass and spring elements along the coil spring.

The onset of reverberation after 20 to 50 milliseconds is effected by a compensating circuit based on the statistical transmission properties of the coil and will be explained in detail later on.

The frequency response of the reverberated signal is determined primarily by the internal friction of the spring. Mechanical vibrating systems generally display a rise in the low frequency response of the reverberated signal, which can be corrected by means of mechanical damping. The frequency response depends on the mass of the

transducer system and the spring parameters as well as on the internal friction. From the users viewpoint a linear frequency response is most desirable as in this way the maximum number of applications is possible.

This additional damping is necessary because variation of decay time which is based on the principle of motional feedback and carried out at the spring ends, only permits a limited control range and, accordingly, initial damping must be provided mechanically. This means that the electronically undamped system must show the longest decay time desired.

The motional feedback principle consists of the pickup of the mechanical signals, the transduction to an analogues electrical signal, the amplification of the signal with the proper phasing, and the electromechanical feedback to the pickup system. Depending on the desired phase and frequency response, we can in this way establish the mass, compliance and friction of the mechanical system.

Having demonstrated the feasibility of the TTL for high quality reverberation and given a rough outline of the various measures used, the portable studio reverberation unit BX 20E developed by AKG will be described in detail.

The BX 20E is based on the principle of torsion transmission and consists of three main parts:

1) the electromechanical reverberation unit proper
2) the electronic circuits
3) the elastic support

The BX 20E is a two channel unit with independent control of decay time of each channel allowing maximum flexibility in stereophonic or monophonic use. The two inputs can be paralleled, and either channel can be used separately.

Reverberation is produced by the torsional vibration of a specially treated coil spring.

The transmission properties of the spring can be calculated by the well known line equations.

For the Mass per unit length

$$L = 2\pi^2 r^3 a^2 \rho \qquad (1)$$

The Compliance per unit length

$$C = \frac{8r}{Ea^4} \qquad (2)$$

The Delay Time is then given by

$$T = W \frac{4\pi r^2}{a} \sqrt{\frac{\rho}{E}} \qquad (3)$$

and the Limiting Frequency is

$$F = \frac{a}{4\pi r^2} \sqrt{\frac{E}{\rho}} \qquad (4)$$

r spring radius

a wire radius

ρ density

E modulus of elasticity

W number of turns in spring per unit length

T delay time

As the reverberation element, a spring which has a double step toward both ends is used as illustrated in figure 1: The length of the spring is 1.2 meters (47.2") to provide the desired 300 milliseconds delay time.

To fit it into a reasonable size enclosure, the spring has been bent twice with special attention paid to avoiding unnecessary reflections. The signal that is to be reverberated enters both ends of the spring by means of moving coil systems and is picked up by similar systems after reverberation.

Each moving coil system consists of two coils which have a rigid mechanical connection between them and which vibrate in a strong magnetic field. The two coils are electrically and magnetically decoupled. The signal is fed into one half and picked up at the other.

Figure 2 shows the moving coil transducer system suspended in the airgap of the circular magnet.

The statistical diffusion of the reverberated signal is achieved partly by statistically changing the surface of the spring wire and partly by deforming individual turns which are distributed irregularly along the length of the spring.

The transmission properties of a coil spring in which torsion vibrations are excited are determined by the mass and compliance per unit length. The mass depends on the third power of the mean diameter of the coil spring, (1) compliance depends on the fourth power of the wire diameter (2). The internal friction of the coil spring is very low. On the basis of these facts it is possible to achieve large variations by relatively small changes of the wire diameter. By etching the wire surface the maximum local removal of wire material results in a 20 per cent reduction of the diameter. These changes, which reduce the mass of the wire and modify the spring elements, are naturally more effective at higher frequencies than at lower ones.

For the lower frequencies, i.e. below 1 kHz, the individual turns are deformed by bending parts of the turns toward the spring axis. Selection of turns that are to be deformed is done statistically. By these means the necessary degree of diffusion is realized. (See figure 3.)

The spring is adjusted to the required output decay time by means of mechanical damping.

Without these mechanical dampings the relation of decay time measured at 50 cycles and 10,000 cycles is on the order of 10 : 1. Figure 4 shows the damper and figure 5 shows this damper built into the spring.

For this reason additional dampers are inserted along the coil spring. Their primary effect is to influence low frequencies under 1 kHz, making it possible to obtain the desired output reverberation frequency response, whose decay time is 6 seconds at 100 Hz, 4.5 seconds at 500 Hz and 2 seconds at 5 kHz. The damper consists of a small disk mounted on an axle. The disk is placed between two washers made of foam material which are in turn slightly pressed against the disk by means of Laminae. The disks are inserted in the spring by disconnecting the spring at various places and soldering the ends to the ends of the disk axle. The choice of diameter and surface of the disk, the selection of foam material, and the determination of the pressure applied permit frequency independent damping within limits. The dampers do not act as impedances on the line so that reflections from them remain within tolerable limits. Apart from providing the desired amount of damping they also serve as excellent protectors from mechanical shock allowing the reverberation unit to be moved without special locking.

As can be seen from the block diagram (figure 6) the electronic portion, for each channel, consists of an input amplifier, an output amplifier, and two attenuation amplifiers. The spring is excited by feeding the original signal into one coil half of each of the moving coil systems arranged at either end of the spring.

The "dry" signal is fed in phase, to each moving coil half on the ends of the spring, the reverberated signal is picked up by the two remaining coil halves, amplified, and connected in opposite phase. In this manner compensation of all interdependent and related signals is achieved, TTL being a reciprocal and passive transmission system.

To illustrate this: If the circuit were to be applied to an ideal line the reflections would all be in phase at the output and would be cancelled by the out of phase connection of the output. However, since the transmission properties of the spring are statistically changed, it produces irregular, statistical, frequency independent reflections which appear at the ends of the spring with no coherence whatsoever. Therefore, these signals will not be cancelled at the out of phase output.

Owing to the diffuse transmission properties of the spring this compensation circuit also provides for 20 to 50 milliseconds delay in the start of reflections after the input of the original signal. This interval is influenced by the degree of diffusion provided for the spring, as through the intensity of etching and the deformation of the ends of the elements the frequency characteristics as well as the absolute value of the start of the reverberated signal can be controlled.

Figure 7 illustrates the above with the use of tonebursts of 300, 600 and 2000 Hz. used as signal frequencies. One division on the screen corresponds to a delay of 20 milliseconds. The maximum value for the onset of reverberation is approximately 50 milliseconds for low frequencies and falls to 20 milliseconds for higher frequencies at which value it remains constant.

Using motional feedback the attenuation amplifier permits the variation of decay time within a certain range. The explanation is as follows: The moving coil systems are deliberately arranged at the spring ends to obtain - inter alia - the greatest possible control of decay time. We know that in an ideal line loaded by its characteristic impedance the decay time is zero. If a simple real resistance is inserted in a line having a large number of inhomogeneities the decay time will not be zero but only approach a minimum because ideal matching is not possible with a frequency independent real resistance. This accounts for the limitations on the control range. The insertion of a real frequency-independent

resistance - is obtained in the following way:

The signal that is to be reverberated is fed into one half of the moving coil system, picked up at the other half, and after a 180° phase inversion again fed into the first coil half. By varying the amplification a larger or smaller friction can be introduced at the spring end. Complete electrical and mechanical decoupling and in-phase mechanical vibration of both coils is essential to their functioning.

The amplification of the attenuation amplifier is electronically controlled by a d.c. voltage. This has many advantages in that remote control is possible, the decay time is insensitive to interference on the control line and it is possible to vary decay time from the control board during recording.

Particular importance must be attached to the last, as decay time can be adjusted to the music without running the risk of picking up undesired and disturbing noise and the like. Thus "true to the score" reverberation is possible.

The amplifier is mounted on a plug-in printed circuit board with one board per channel and uses integrated circuits for maximum reliability. The input and output levels are adjusted to the requirements of studio techniques at + 6db, with the input impedance at 1 kΩ and an output impedance of 50Ω. Both channels are completely symmetrical.

The elastic suspension of the reverberation unit has to fulfill two functions; isolation from footsteps and floorborne sounds on one hand and protection from shock during transportation on the other hand. Attention must also be paid to careful insulation against air borne sound, as undesired feedback might occur.

The two springs together with the magnet systems and the various supporting and securing elements form a unit which is mounted in a cardboard tube. The inside

of the cardboard tube is lined with a porous foam material into which the unit is tightly mounted. This results in both excellent damping and the absence of membranelike vibrations of the wall since the internal friction of cardboard is so high.

The cardboard unit is mounted inside an elastic single point pendulum suspension whose natural resonances, determined by the length of the pendulum, the weight of the unit, and the spring constants, is below 1 Hz. These low suspension resonance frequencies are necessary because, owing to their length, the reverberation springs show natural resonances between 5 and 10 Hz even with dampers inserted.

The whole unit is mounted in a strong wooden housing which has an additional sound insulating effect. The back panel of the housing is a door on the inside of which the amplifiers are mounted and on the outside the connector plate is fastened. Intercepting drums are elastically arranged above and below the cardboard tube to prevent it from striking the wooden wall under extreme shock or when the unit is overturned. They have the disadvantage that in normal operation the maximum angle of inclination of the housing is restricted. Owing to these mounting techniques it has become possible to avoid locking the unit during transportation. Thus the danger of minor jerks acting directly upon the system and keeping the spring in constant motion has been avoided and the danger of fatigue breaks is greatly reduced. (See figure 8 and figure 9.)

With the BX 20E AKG has succeeded in developing a remotely operated unit whose reverberation meets all the requirements and demands of studio technique, guarantees excellent acoustic fidelity of the reverberated sounds, and is entirely free of coloration, flutter echoes, and similar disturbances.

The unit has met with considerable success both in Network and Studio use where its quality of reverberation has been favorably compared to that of a concert hall.

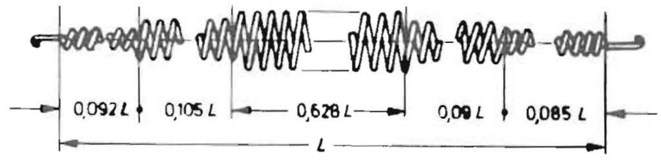


Figure 1

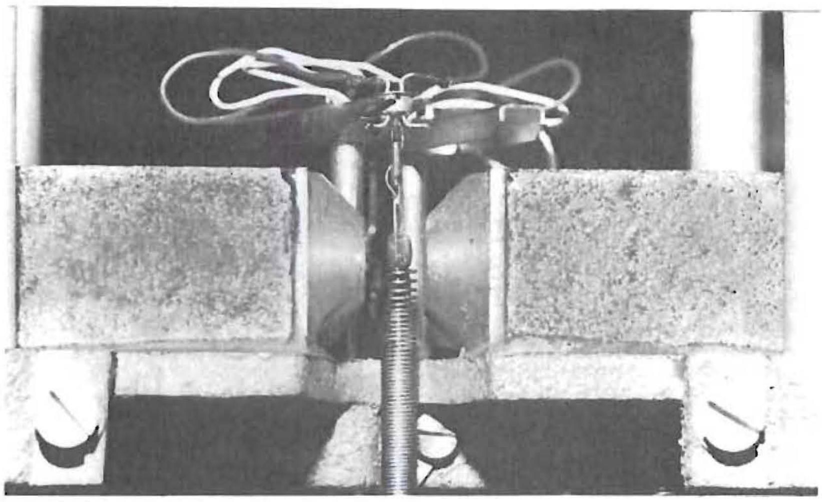


Figure 2

Figure 4

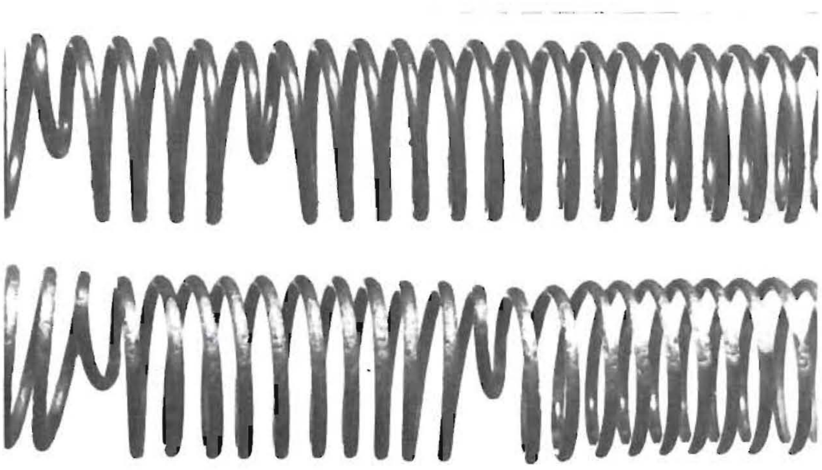


Figure 3

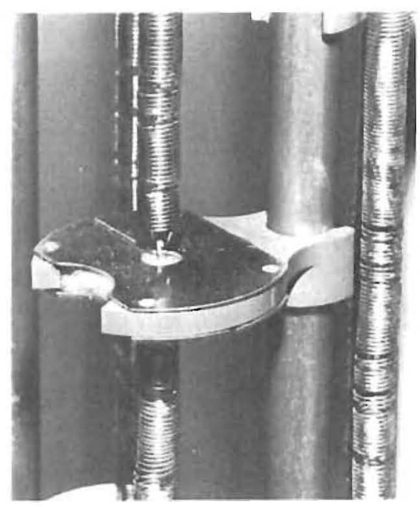
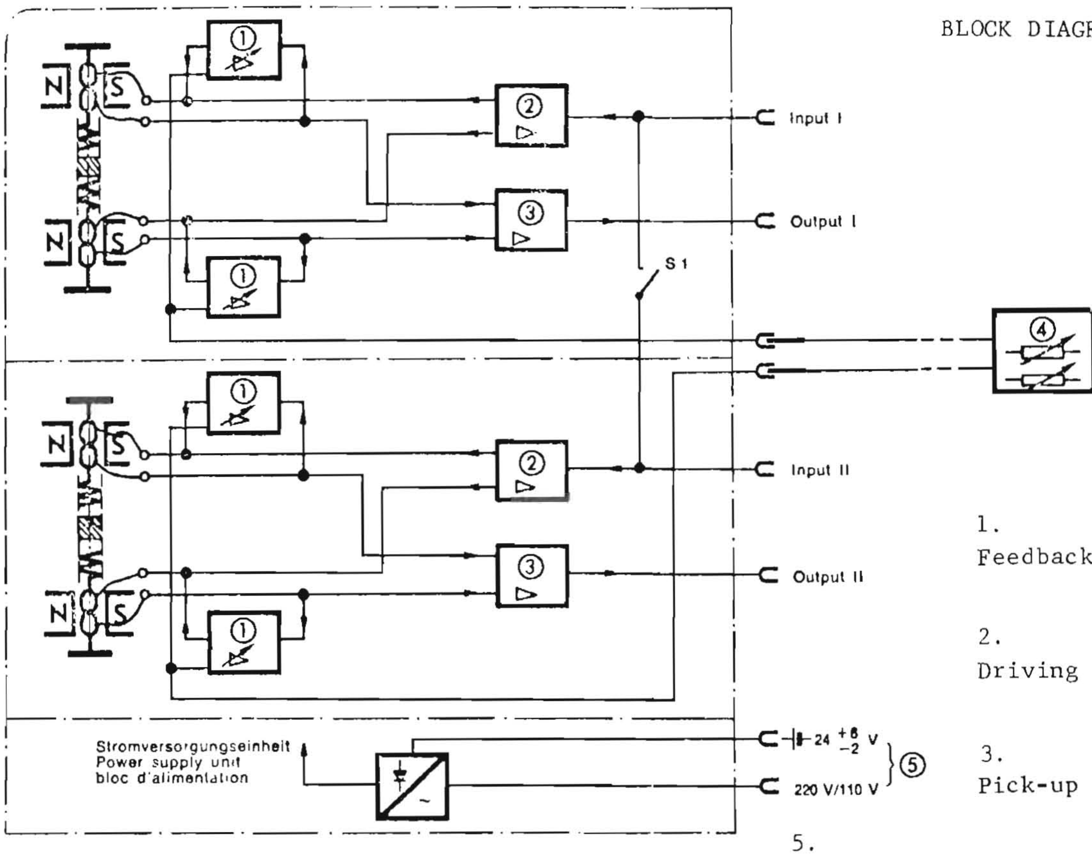


Figure 5

BLOCK DIAGRAM



1.
Feedback amplifier

2.
Driving amplifier

3.
Pick-up amplifier

4.
Remote control unit R 20E with remote control line

5.
Automatic switch-over from mains supply to battery supply

Figure 6

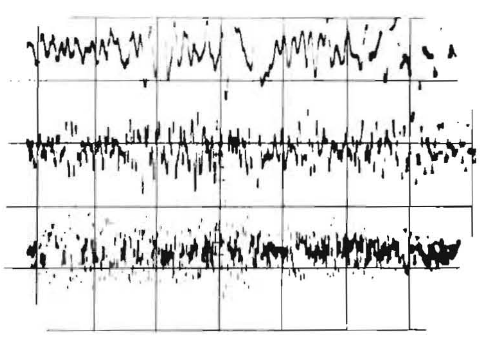


Figure 7

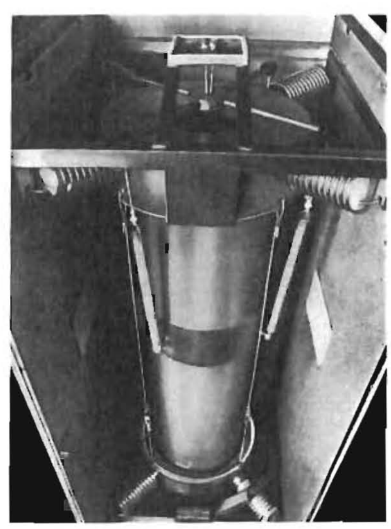


Figure 8

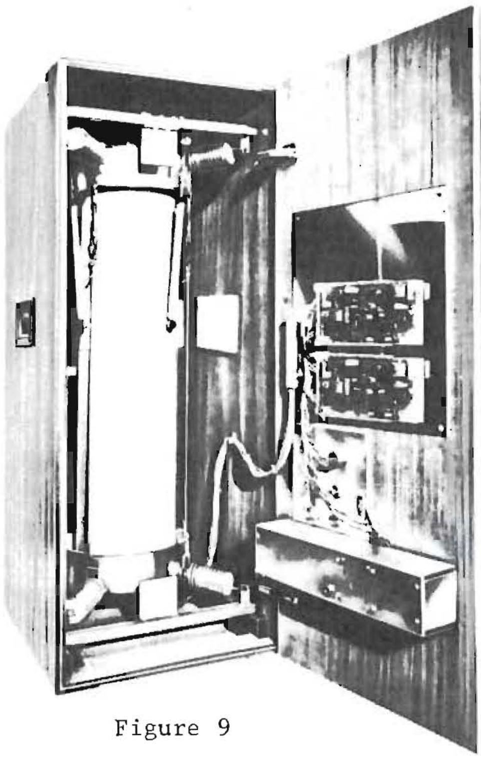
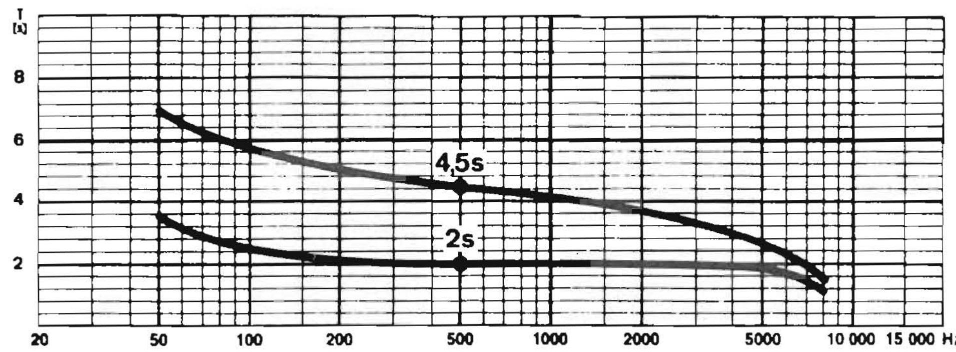
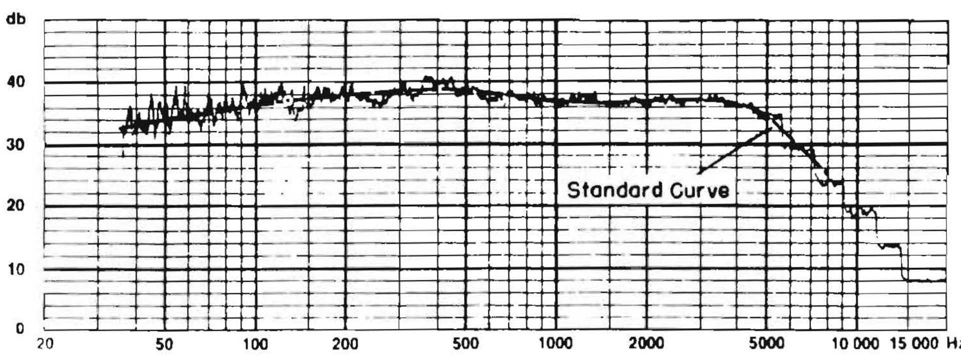


Figure 9

Remote control unit R 20E



Frequency response of decay time



Frequency response of BX 20E
measured with 1/3 octave-noise